A NEW METHOD OF PRODUCING RIPPLES. OPTICAL ANALOGIES.

By A. H. Pfund.

THE use of ripples in illustrating optical phenomena is too well established to require justification. Since the publication of Vincent's[1] work on mercury ripples, little has been or can be added to the discussion of the application of these phenomena to experiments in optics. In view of their recognized pedagogical value, it seems strange that but little use is made of ripple experiments in lecture-room demonstration. The reason for this becomes apparent, however, when the complexity of the apparatus, necessary for producing ripples and making them visible, is taken into con-

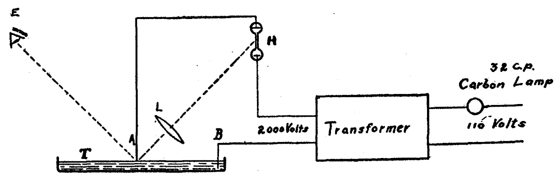


Fig. 1.

sideration. Recently I observed a phenomenon which was used as the essential feature in the construction of a ripple apparatus of great simplicity. The following diagram (Fig. 1) shows the complete apparatus.

The current from the secondary of a small transformer (2,000 volts, 60 cycles per second) passes through a helium vacuum tube H, then through the wire A (0.5 mm. diameter) into distilled water contained in the hard rubber tray T and finally back through the wire B to the transformer. While the wire B dips deeply into the water, the wire A just touches the surface—and it is at this point that the ripples are produced. The fact that the phenomenon is

[1] J. H. Vincent, Phil. Mag., 1897, 43, p. 417; 1898, 45, p. 191. H. M. Reese, Ap. Jnl., 1906, 24, p. 47.

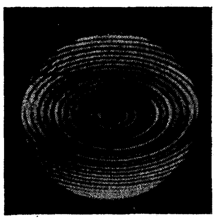


Fig. 3.

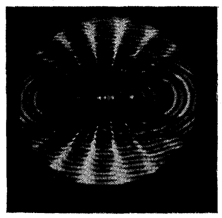


Fig. 4.

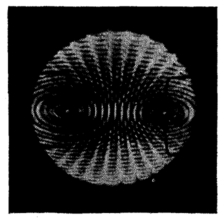


Fig. 5.

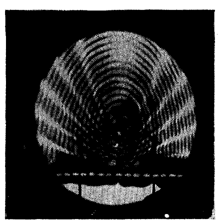


Fig. 6.

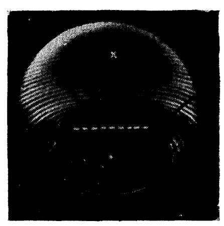


Fig. 7.

A. H. PFUND.

observed only when such poorly conducting liquids as distilled water and alcohol are used, indicates that the ripples are produced by the effect of the large potential drop at the point of contact. No mechanical vibration of the wire A is present.

Each pulsation of the current produces a ripple which moves out from its source with so great a velocity that, in continuous illumination, the surface of the water appears undisturbed. However, by making the illumination intermittent, *i. e.*, synchronous with the rate of production of ripples (which is accomplished by the use of the vacuum tube H), the ripples apparently stand still and may be observed at leisure. For observing or photographing ripple-phenomena, the lens L is placed as indicated in the diagram

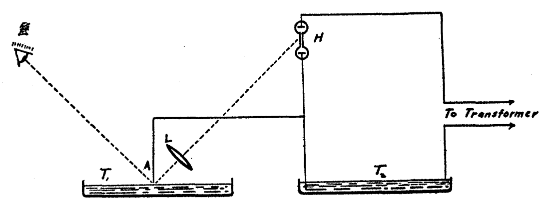


Fig. 2.

where the helium tube and the eye or camera lens are at conjugate foci. So as to obtain light from a "point" source, all light coming from the helium tube, with the exception of that coming from 1 mm. of the capillary, was screened off.

That the ripples are produced by electrostatic effects is further proved by the effects observed with the apparatus arranged according to diagram shown in Fig. 2. Here the current passes through the vacuum tube H and then through distilled water in tray T_2 (this water merely serves as a high resistance). The end of the wire A does not touch the surface of the water in tray T_1, but is brought as near it as possible without making contact. The eye placed at E sees beautiful ripples having A as their center.

The proper contact, necessary for giving the phenomenon at its best must be determined by trial. If the lower end of the wire A (Fig. 1) is too high above the general surface of the water, the ripples are too violent; if, on the other hand, the wire dips down into the water too deeply, the ripples are too feeble.

In order to avoid annoying reflections at the sides of the containing vessel, it is necessary to remove all traces of grease so that the water may be drawn up slightly where it meets the vessel. If, however, reflections are desired, a piece of glass or sheet-metal, covered with grease is placed into the water.

In explanation of the photographs it might be stated that, as a consequence of viewing the water-surface at an angle of about 45°, the reflected image of the wire *A* is always visible and the otherwise circular ripples appear elliptical. Whenever any object is placed in the water, the planarity of the surface is destroyed and, in consequence, a dark region of considerable extent is produced—making it difficult to determine the character of the object from the photograph. Whenever necessary, I have indicated with dotted lines the position of the object in question. The photographs here presented show only a few of the results which may be obtained with this particular arrangement of apparatus. Many modifications suggest themselves for showing more complicated phenomena, but, as these advantages are gained at the expense of simplicity, I have decided not to discuss them at present.

Fig. 3. This illustrates the character of ripples from a single point source.

Fig. 4. This illustrates Young's interference experiment. Two point sources, vibrating in phase, give rise to interference hands whose loci in space are confocal hyperbolæ of revolution (the sources lying at the foci). The existence of hyperbolæ is well shown in the photographs. To obtain these results, the current is led into the water by both wires.

Fig. 5. This shows the same phenomenon with wide separation of sources. The narrowness of the interference bands, as contrasted with the preceding case, is to be noted.

Fig. 6. The analogy of Lloyd's mirror is here shown. A greased piece of brass, at a distance of 1 cm. from the source, acts as a plane mirror—the incident and reflected waves interfering to show well-marked interference bands. As is well known, the waves leaving the reflector seem to come from a source situated as far behind the mirror as the real source is in front of it. As a result, interference bands of the same type as those shown in Figs. 4 and 5 are

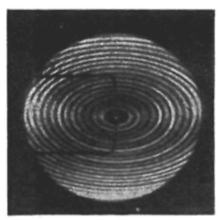
produced. The reflector simply rests in the water and is not electrically connected.

Fig. 7. Here the ripples are produced by a point source in front of an obstacle and the phenomenon within the gemoetrical shadow is photographed. In the illustration it is first to be observed that the ripples rapidly enter the region of the geometrical shadow (diffraction). These diffracted waves, coming from the two edges of the obstacle, produce an interference pattern which could be duplicated by two real sources—one at each corner of the obstacle. This becomes evident from the hyperbolical form of the fringes. The straight central fringe (x) represents the analogy of Poisson's famous experiment.

Of the many other experiments which I have carried out with this apparatus, the one illustrating refraction is worthy of particular notice. This phenomenon was observed by floating a drop of machine oil on the surface of the water. The drop slowly expands into a circular disc on whose surface ripples are observed. Since the surface-tension of oil is much less than that of water, the velocity of the ripples is less on the oil surface, hence the waves are refracted. The phenomenon, though readily observable, was not photographed for the reason that during the necessary time of exposure (three minutes) the drop had expanded to such an extent that it covered the entire surface of the water.

In conclusion I wish to repeat that the only novelty claimed for these experiments lies in the simplicity of the method of producing ripples and making them visible. If this discussion will help in bringing about a more widespread use of ripples in the elucidation of optical principles, I shall consider my purpose in writing this note well accomplished.

Johns Hopkins University,
October, 1910.



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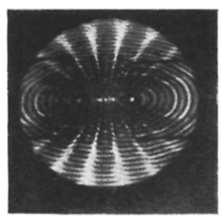
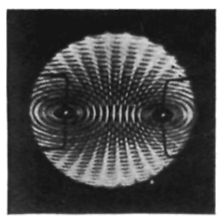


Fig. 4.



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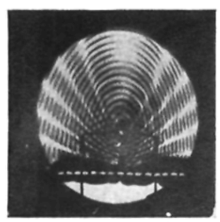

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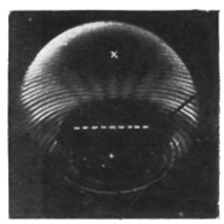

Fig. 7.